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Effective Energy Utilization in Mobile Ad hoc Networks using Cross Layer Framework

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Abstract: **A mobile ad-hoc network (MANET) is a temporary infrastructure less multi-hop wireless network in which the nodes can move arbitrarily. The nodes make use of Dynamic Source Routing Protocol (DSR) which collects the route information through overhearing and stores these information in route caches. The overhearing improves the network performance but consumes energy unnecessarily and this can be reduced using RandomCast mechanism. This mechanism reduces energy consumption but the node mobility results in more stale routes in route cache of DSR over a period of time. This occurs due to the lack of route cache updation. So, a cross layer framework is implemented to improve route cache performance in DSR. Here cache timeout policy prevents stale routes from being used. The cache timeout of individual links in route caches are found by RSSI information. The implementation of cache timeout policy ensures cache freshness in DSR which assures reliable end to end packet delivery.**

Keywords - MANET, DSR, Stale route , Cache timeout policy and RSSI.

I. INTRODUCTION

In ad-hoc network, the nodes are mobile and can communicate dynamically in an arbitrary manner. The major concern in MANET is the conservation of energy due to the limited lifetime of mobile devices. The main objective is to make the 802.11 PSM applicable in multihop MANET with Dynamic Source Routing (DSR) protocol and an additional energy is saved by identifying and eliminating unnecessary communication activities. The drawback in integrating the DSR protocol with 802.11 PSM [4] [6] comes from unnecessary or unintended overhearing and DSR depends on broadcast flood of control packets [5]. So to fulfil the objective and to overcome the drawbacks, a message overhearing and forwarding mechanism called RandomCast [1] is chosen which makes a judicious balance between energy and network performance.

The on-demand routing protocols DSR [12] and AODV [13], before sending a packet to the destination, discovers a route. Route maintenance is invoked when node detects link failure. In order to avoid route discovery for each packet, on-demand routing protocols utilizes cache routes previously learnt.

DSR gathers the route information through overhearing. Overhearing improves the routing efficiency in DSR by eavesdropping other communications to gather route information but it spends a significant amount of energy. In the RandomCast mechanism [11], a node may decide not to overhear i.e. a unicast message and not to forward and a broadcast message when it receives an advertisement during an ATIM window, thereby reducing the energy cost without affecting the network performance. In addition to the energy consumption, overhearing brings in several undesirable consequences. It could aggravate the stale route problem, the main cause of which is node mobility.

But AODV takes a conservative approach to gather route information [14]. It does not allow overhearing and eliminates existing route information using timeout. This necessitates more RREQ messages which in turn results in more control overheads in routing**.**

The performance of on-demand routing protocols, therefore, heavily depends on efficient implementation of route cache. This involves cache structure, cache capacity and cache timeout policy. The time varying topology of ad-hoc network, which results from node movement, makes cache entry stale over a period of time. Therefore, a cache timeout policy [3] is required to predict route cache lifetime, and to expunge stale route cache entries, which are timed out. Deriving proper cache timeout policy thus plays an important role for ensuring cache freshness. Many techniques have been proposed for route cache organization and its effect on the performance of on-demand routing protocols. But the concentration of cache timeout policy is very less.

It is used in route cache implementation to prevent stale route from being used. So, a technique for reducing the unintended overhearing of neighboring nodes is done with the help of RandomCast mechanism and for prevention of stale route problem, a cross-layer cache timeout policy is implemented. Time out policy derives cache timeouts of individual links that are present in route cache by utilizing Received Signal Strength Indicator (RSSI) information.

The paper is organized as follows. The Section 2 describes with overview of DSR protocol. Section 3 deals with the levels of overhearing and stale route problem in DSR. Section 4 is devoted for the implementation of cross layer framework. Section 5 describes the performance analysis and the last section concludes the work.

II.OVERVIEW OF DSR PROTOCOL

The DSR is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad-hoc networks of mobile nodes. Using DSR, the network is completely self-organizing and self-configuring, requiring no existing network infrastructure or administration. Network nodes cooperate to forward packets for each other to allow communication over multiple "hops" between nodes. Since the number or sequence of intermediate hops needed to reach any destination may change at any time, the resulting network topology may be quite rich and rapidly changing. The DSR protocol is composed of two main mechanisms that work together to allow the discovery and maintenance of source routes in the ad-hoc network.

Route Discovery is one in which a node S wishing to send a packet to a destination node D obtains a source route to D Route Discovery is used only when S attempts to send a packet to D and does not already know a route to D.

Route Maintenance is one in which node S is able to detect, while using a source route to D, if the network topology has changed such that it can no longer use its route to D because a link along the route no longer works. When it indicates a source route is broken, S can attempt to use any other route it happens to know to D, or it can invoke Route Discovery.

In DSR, Route Discovery and Route Maintenance each operate entirely "on demand". In particular, unlike other protocols, DSR requires no periodic packets of any kind at any layer within the network. When a node has a data packet to send but does not know the routing path to the destination, it initiates the route discovery procedure by broadcasting a control packet, called route request (RREQ). When an RREQ reaches the destination, it prepares another control packet, called route reply (RREP), and replies back to the source with the complete route information. Upon receiving an RREP, the source saves the route information in its local memory, called route cache, for later uses. When a node detects a link error during its data transmission, it sends another control packet, called route error (RERR), to the source and deletes the stale route from its route cache. Overhearing improves the network performance by allowing nodes to collect more route information. Nodes in the vicinity of a transmitter would learn about the path to the destination via overhearing.

III. LEVELS OF OVERHEARING AND STALE ROUTE PROBLEM IN DSR

In addition to the energy consumption overhearing brings in several undesirable consequences. The main cause of the stale route problem is the node mobility in DSR.

A. Levels of Overhearing

There are three cases based on the level of overhearing. They are as follows,

1) No Overhearing

It is assumed that node S transmits packets to node D through a precomputed routing path with three intermediate nodes.

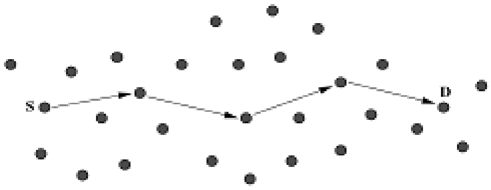

Fig. 1. No Overhearing

No overhearing is shown in Fig.1, only five nodes are involved and the others would not overhear it.

2) Unconditional Overhearing

It is shown in the Fig. 2, that node S transmits packets to node D through a precomputed routing path with three intermediate nodes but in this case each and every node overhears the transmission which results in the energy consumption as well as less network lifetime.

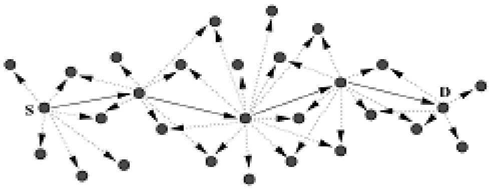

Fig. 2. Unconditional Overhearing

3) Randomized Overhearing

This overhearing adds one more possibility between the two which is nothing but some of the neighbors overhear it but others do not. The nodes which do not overhear will switch to low power sleep state which results in the energy saving compared to unconditional overhearing. In the Fig. 3, nodes A and B are two intermediate nodes along the path from node S to D. Node B forwards an RREP to node A and later node A forwards a number of data packets to node B.

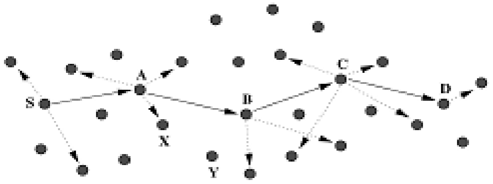

Fig. 3. Randomized Overhearing

Nodes X and Y are two neighbors of A and B, and they will learn about the routing path by overhearing any one of the communications between nodes A and B. If the overhearing is conditional then the control overheads can be reduced.

B. *Stale Route* links *Problem in DSR*

The wireless break due to the node mobility and an upstream node propagates a RERR packet to remove stale route information from route caches of the nodes. RERR information is not propagated “fast and wide”. Route caches often contain stale route information for an extensive period of time. Now, overhearing could make the situation even worse. This is because that DSR generates more RREP packets for a route discovery to offer alternative routes in addition to the principal one. While the primary route is checked for its validity during the communication between the source and the destination, alternative routes may remain in route cache unchecked even after they become stale. This applies also for all their neighbors because they learned and kept them by means of unconditional overhearing.

IV. IMPLEMENTATION OF CROSS-LAYER FRAMEWORK

A node in an ad-hoc network learns routing information by overhearing or forwarding packets to other nodes and keeps the learned routes in the route caches. The RandomCast for both unicast and broadcast packets has been discussed below,

A. *RandomCast, an Overhearing and Forwarding Mechanism for Unicast Packets*

The mechanism enables a transmitter to choose no, unconditional, or randomized overhearing for its neighbours, specified in the ATIM frame and is available to its neighbouring nodes. For practicality, it is implemented in the context of IEEE 802.11 specification by slightly modifying the ATIM frame format

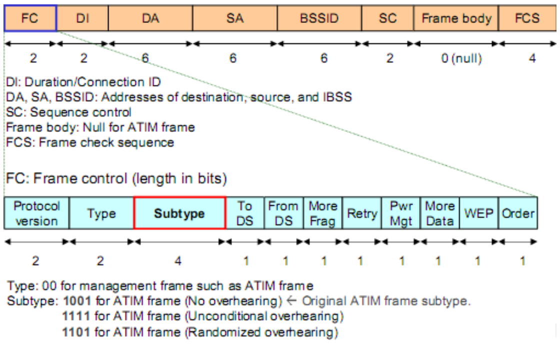

Fig. 4. ATIM Frame Format

ATIM frame is a management frame (type 00_2) and its subtype is 1001_2 according to the 802.11 standard. The RandomCast protocol utilizes two unused subtypes, 1101_2 and 1110_2, to specify randomized and no overhearing, respectively. An ATIM frame with the original subtype 1001_2 is recognized as unconditional overhearing and thus conforms to the standard. When a node (its MAC address MA) wakes up at the beginning of a beacon interval, it receives an ATIM frame or a unicast packet. The ATIM frame contains the receiver address (DA) and subtype (ID). The node decides whether or not to receive/overhear the advertised packet in the following data transmission period based on DA and ID. It would remain awaken to receive it if one of the following conditions is satisfied:

1. The receiving node is the anticipated destination.
2. If the node is not the destination and unconditional overhearing is opted.
3. If the node is not the destination, the randomized overhearing is opted.

For each of the unicast packets, DSR uses the following overhearing mechanism, they are as follows,

  a. Randomized overhearing for RREP packets
  b. Randomized overhearing for data packets
  c. Unconditional overhearing for RERR packets

B. *RandomCast, An Overhearing and Forwarding Mechanism for Broadcast Packets*

This overhearing and forwarding mechanism can be applied to the broadcast packets such as RREQ to allow randomized overhearing; this avoids redundant rebroadcast of the same packet in dense mobile networks. On the other hand, the rebroadcast decision must be made conservatively. This is because a broadcast packet may not be delivered to all nodes in the network when conditional rebroadcast is used. The rebroadcast probability (P_F) is set higher than overhearing probability (P_R). In overhearing, different broadcast packets are given, they are as follows

  i. Randomized rebroadcast for RREQ packets
  ii. Unconditional rebroadcast for ARP (address resolution protocol) request

Even though RandomCast reduces energy consumption by allowing the sender to specify the desired level of overhearing, the problem arises due to node mobility since the node mobility results in stale routes in route caches. This stale route problem will again be a cause for energy consumption. To make the RandomCast mechanism more effective stale route avoidance is necessary and this is done by implementing the cross layer framework which depends on cache timeout policy.

C. *Stale Route Avoidance in DSR by Cache Timeout Policy*

Nodes movements result stale route cache entries. Cache staleness is a big problem in link cache scheme where individual links are combined to find out best path between source and destination. A cache timeout policy is required to expire a route cache entry, when it is likely to become stale. DSR makes aggressive use of route cache to avoid route discovery. The performance of DSR heavily depends on efficient implementation of route cache. In this, a new cross-layer approach for predicting the route cache lifetime is presented. This approach assigns timeouts of individual links in route cache by utilizing RSSI values received from wireless network interface card.

The cross-layer framework is based on link cache implementation. In general, detecting a broken link is very expensive, due to the number of retransmissions required before a node can know that link has broken, further, exponential backoff performed for each retransmission attempt results significant delay and network overhead. The received signal strength P_r, of a received packet varies with distance d, as follows:

$$\text{Received power } P_r \propto \frac{P_t}{d^n} \qquad \text{- (1)}$$

Here n varies from 2 to 4, and P_t denotes transmit power used by the source. As node moves, distance between them d, either decreases (nodes moving close to each other) or Increases (nodes moving away of each other) and therefore received P_r value. Received signal strength Pr may vary because of channel fading and or other transient interference. The IEEE 802.11 standard specifies implementation of RSSI as an optional entity. It has been observed that node movement results change in observed RSSI values and a link that has low RSSI value is more likely to be broken. Therefore when a node learns link information, it assigns link timeout in route cache according to RSSI strength. We define a set of exponentially increasing RSSI value thresholds R_0, R_1, …, R_n. The threshold R_0 is the minimum and R_n is the maximum one. To derive this series of thresholds a number of parameters need to be taken into account. This includes ad-hoc network geometry, mobility model, communication model, and number of nodes. For a given adhoc network configuration, this set of thresholds shall be determined by obtaining a histogram of RSSI values through simulation on original ad-hoc network configuration.

The framework captures variation of RSSI values due to node movements. When nodes move away, they observe decreasing RSSI values for the received packets. Therefore, link timeout can be predicted and it can be removed from the route cache before a node discovers it stale. The set of thresholds R_0, R_1, …, R_n, assigns higher timeout to those links that are learned with higher RSSI values. A link (i, j) in the route cache will be assigned large or small timeout depending upon whether the distance between the nodes i and j is small or large. The overhead of the proposed framework is extremely low. There is no routing overhead introduced. The framework requires RSSI thresholds to link timeout mapping table on every node of the ad-hoc network. The size of this table can be decided based on individual node's local storage availability.

D. Algorithm

The steps for transmitting an ATIM frame is as follows

1. First RREQ packet will be broadcasted to all the nodes in the network.
2. The overhearing level will be set in the frame type field of ATIM for the unicast data packets like RREP and RERR.
3. Nodes in the network may overhear the RREP and stores the route information in route caches based on the subtype.
4. If there is any link break, RERR is propagated to the source node by an upstream node so that it can be deleted these stale route from route cache.
5. This stale route information will be present in some of the neighboring nodes due to the overhearing of RREPs.
6. Route cache is updated by cache timeout policy to remove stale routes from the neighboring nodes.
7. This updation is done based on the RSSI values.

Cache Freshness Routing Algorithm:

```
/* RERR is overheard unconditionally and RREP is
randomized*/
{
if ( SA = = unicast )  RERR is transmitted
if ( OL = = unconditional )
else if ( $P_R \geq P_F$ )
else ( ID = 1001 )
{
else ( OL = randomized )
if( rand(0,1) ≤ $P_F$ ) send an ATIM frame
}
}
/* Cache timeout policy */
{
if( RSSI > T )
No route cache updation is required
else route cache is updated
}
```

V. PERFORMANCE ANALYSIS

The analysis of the work is carried out in the NS2 simulator under LINUX platform. For the analysis, wireless transmission is chosen with two-ray ground propagation model with IEEE 802.11 MAC. The routing protocol is DSR and the area of the network is Mobile Ad-hoc network. For analyzing the performance of the work, 50 nodes are considered with the node speed of 30 m/s and a packet size of 256 bytes/sec.

Fig. 5, presents the energy consumption. The Comparison of energy consumption for RandomCast using DSR-X and RandomCast using DSR is shown. It is clearly seen that energy consumed by RandomCast using DSR-X is less compared to RandomCast using DSR.

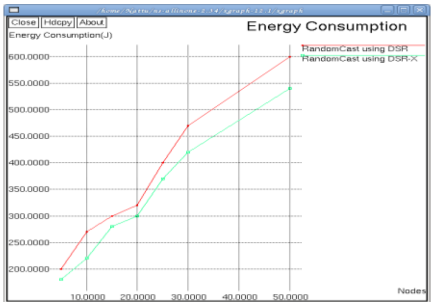

Fig. 5. Comparison of Energy Consumption

Fig. 6, presents Packet Delivery Ratio comparison and the results show that packet delivered in RandomCast using DSR-X is high compared to RandomCast using DSR. When the packet delivery ratio is greater, reliability of the network will also be greater.

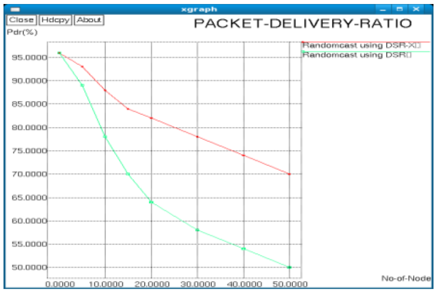

Fig. 6: Comparison of Packet Delivery Ratio

Fig. 7, presents the comparison of Throughput. Throughput or network throughput is defined as the average rate of successful message delivery over a communication channel. It is clearly shown that the throughput of RandomCast using DSR-X is high compared to RandomCast using DSR.

Fig. 7. Comparison of Throughput

Fig. 8, presents the comparison of delay for RandomCast using DSR-X and RandomCast using DSR and is seen that Delay for RandomCast using DSR-X is less compared to RandomCast using DSR.

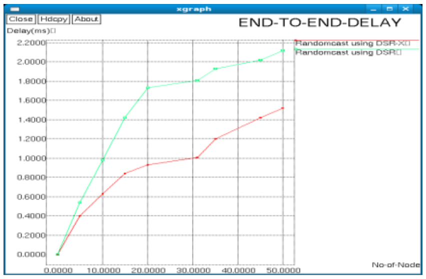

Fig. 8. Comparison of End-to-End Delay

VI.CONCLUSION

It is seen from the simulation analysis; energy is utilized effectively in MANET by the cross-layer framework implementation. DSR proves to be more efficient than AODV because of less overhead. DSR gathers the route information through overhearing during every data transmission. This overhearing improves the network performance at the cost of unnecessary energy consumption. The RandomCast mechanism is designed such that the sender can specify the desired level of overhearing based on the number of neighbors, which reduces the energy consumption. The overhearing nature of DSR results in stale routes so route cache updation is done by cross-layer framework implementation. It is based on the cache timeout policy which prevents stale routes from being used. The cache timeout of individual links in route caches are found by RSSI information. The implemented cache timeout policy ensures cache freshness in DSR and the results indicate reliable end to end packet delivery.

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